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Tapping the Leakages: Methane Losses, Mitigation Options and Policy Issues for Russian Long Distance Gas Transmission Pipelines

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Abstract:

The Russian natural gas industry is the world's largest producer and transporter of natural gas. This paper aims to characterize the methane emissions from Russian natural gas transmission operations, to explain projects to reduce these emissions, and to characterize the role of emissions reduction within the context of current GHG policy. It draws on the most recent independent measurements at all parts of the Russian long distance transport system made by the Wuppertal Institute in 2003 and combines these results with the findings from the US Natural Gas STAR Program on GHG mitigation options and economics.

With this background the paper concludes that the methane emissions from the Russian natural gas long distance network are approximately 0.6 % of the natural gas delivered. Mitigating these emissions can create new revenue

streams for the operator in the form of reduced costs, increased gas throughput and sales, and earned carbon credits. Specific emissions sources that have cost-effective mitigation solutions are also opportunities for outside investment for the Joint Implementation Kyoto Protocol flexibility mechanism or other carbon markets.

Keywords: Russia, long distance natural gas pipelines, methane recovery, GHG mitigation, flexible mechanisms

1. Introduction

Direct GHG emissions associated with the end use of natural gas are smaller than other fossil fuels. Replacing fossil fuels with natural gas is therefore a practical measure to address climate change policy of increasing energy efficiency and switching to renewable energy sources. As a consequence, the role of natural gas in the European energy market has been increasing in the last decade. In parallel with increased natural gas use, the issue of indirect GHG emissions from gas production and transport - especially in and from Russia - has come up in the discussions about the energy supply in Europe (cp. Lechtenböhmer et al., 2003).

A comprehensive measurement campaign of the Russian Northern and Central export pipelines was carried out by Wuppertal Institute in cooperation with Max-Planck Institute for Chemistry (with support of Gazprom, E.ON-Ruhrgas and VNIIGAZ Institute) in 2003. The purpose of the campaign was to close the gaps in the available data and improve the knowledge of the methane emissions from the gas export grid in Russia (Lechtenböhmer and Dienst et al., 2005). Based on the results of the measurement campaign, this paper surveys the existing options for mitigation actions. The extensive works of the Natural Gas STAR

International Program, a voluntary partnership between the US EPA and natural gas operators to reduce methane emissions, illustrate that gas capture projects are profitable due to the increased throughput and increased efficiency. Additionally the options of the Kyoto flexibility mechanisms as mitigation policy are discussed.

2. Background and Methodology

Background

The Russian Federation, with proved gas reserves of 47,000x10^9 m^3, is the world's largest producer of natural gas (580x10^9 m^3 per year). As the major gas supplier to the European Union (115x10^9 m^3 per year) (BP 2004), Russian Federation pipelines span the 5,000 km gap between production in West-Siberia and the consumers in Mid-Europe. The Russian market leader, Gazprom, operates one of the largest long distance gas networks, which consists of about 153,000 km of gas pipelines. The gas lines in the Gazprom network were mainly installed between the 70s and 90s (Lelieveldt et al., 2005).

In the first half of the 90s, most statements made on methane emissions from the Russian natural gas export system were based on rough assumptions (Rabchuk et al., 1991; Dedikov, 1999). To obtain reliable information on emissions, measurements were conducted on the Gazprom gas transmission network. In 1995, measurements were made by US EPA and Gazprom (1996); in 1996/97, additional measurements were made by Gazprom and Ruhrgas (Dedikov, 1999; Kobzev, 1997).

The reference figures derived from these measurements were of comparable orders of magnitude. Both studies put the methane emissions from the Russian gas transmission network at approximately 1 % of the natural gas produced.

These findings suggested significantly lower emissions than had previously been assumed. On the other hand they met some criticism concerning the small number of sites surveyed, a lack of transparency, and missing detailed documentation (cp. Popov, 2001; Lechtenböhmer et al., 2003, 2005). In addition to the measurements, opportunities and recommendations for emission reduction in Russia have been composed by US EPA and Gazprom (1998).

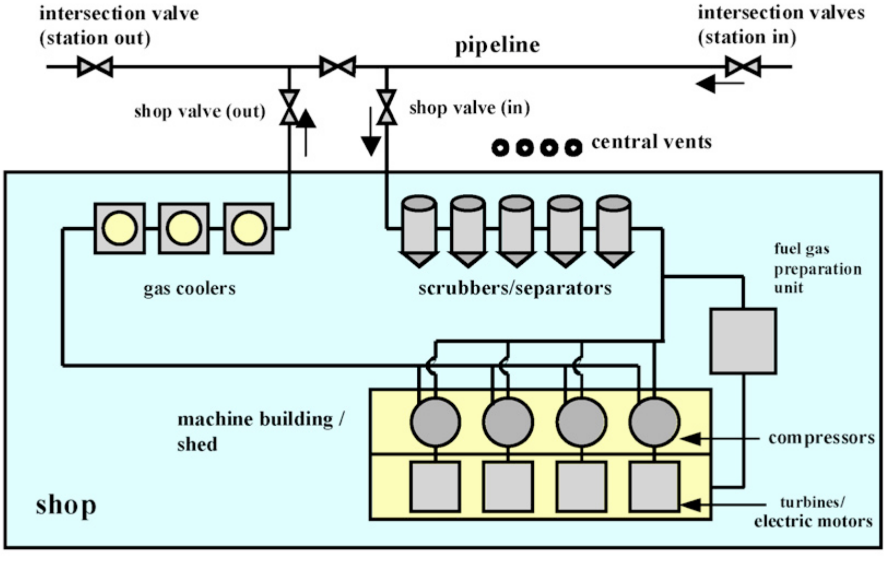
In 2002, other campaigns were carried out to detect and repair methane leakages at compressor stations (Venugopal, 2003) and (Mandra and Novakivska, 2003). Venugopal reports on work at two Gazprom compressor stations on the Nizhny Novgorod transmission system quantifying methane losses at $21.5x10^6$ m^3 per year. Mandra and Novakivska report on work at two Cherkasytransgaz compressor stations quantifying methane losses at $2.958x10^6$ m^3 per year.

Methodology

To verify the results of the previous studies, analyse the uncertainty more accurately, and close gaps in the available activity data and specific emission factors, the Wuppertal Institute together with the Max Planck Institute for Chemistry in 2003 (with technical assistance from Ruhrgas, Gazprom, VNIIGAZ Institute) conducted a new and independent methane emission measurement program. The actual scheme of the measurement program's data extrapolation and error analysis were designed and implemented in accordance with the relevant requirements for GHG inventories (IPCC, 1996, 2000; GRI/US EPA, 1996). The measurements were carried out at five selected compressor stations and adjacent pipeline sections. They represent the two major Gazprom export corridors and their range of different geographical and infrastructural factors, as well as different ages, types of compressors, and pipelines sections.

A systematic inspection and survey of individual plant sections at the compressor stations such as compressors, dust filters, gas driers, gas coolers, etc. was carried out. It included several steps starting with the identification and listing of all units at the compressor stations, including valve nodes/intersections at adjoining pipeline sections. A thorough screening at the identified locations with sensitive methane detectors was conducted, followed by documenting and marking places with elevated methane levels. Methane leakage rate measurements by the flux method (wrapping of the leak, sucking of a defined volume of air and gas by a pump, and measurement of methane concentration in sucked air) were conducted in the marked locations. Numerous vents installed on machines, fittings, and fuel gas supplies for the controlled discharge of gas have been subjected to direct volumetric measurements. To get an idea of how a compressor station is structured, a plan of a compressor station is shown in Fig. 1.

Figure 1: Compressor station



Source: Wuppertal Institute 2004

To determine not only gas losses due to leaks, but as well the so-called operations-related discharges, operational data was collected in situ on location and a large amount of internal data on the two export corridors was provided by Gazprom and VNIIGaz Institute (2004). The discharges are a function of the mode, operating characteristics and parameters of the machinery and plant. For the structured collection of the data needed, a questionnaire had been prepared and was used at the sites to gather the operational data in liaison with the station managers and engineers responsible.

After the measurements and data collection on location, a Monte-Carlo simulation was carried out to provide an extrapolation of the results with a sound measure of the uncertainty incorporated for the gas exports to Western Europe via the two main export corridors (as documented in Lechtenböhmer and Dienst et al., 2005) and for the Russian long distance pipeline grid as a whole (as documented in Lelieveld et al., 2005). For this simulation the single measurements from the respective components surveyed (see number and description in Table 1) have been converted into probability density functions describing the probability of the existence and the size of a leak at the respective type of equipment. In the next step the values have been extrapolated to the total number of such potentially emitting components in the whole Gazprom system by simulating random emissions for each component operated. This has been repeated 10,000 times to simulate all possible combinations of random results and determine the respective confidence intervals (see Table 3). The Monte-Carlo simulation is internationally regarded as the most appropriate method for determining the uncertainties of GHG inventories (IPCC, 2000. GRI/US EPA, 1996). For this random-based uncertainty simulation, two basic assumptions had to be made. First, the assumption of identical distributions of leak incidence and emission levels of all the leaks from a component type; second, the assumption of a virtually constant emission situation over the course of the year.

3. Measurements and empirical survey

A total of three measurement trips to five compressor stations and associated sections of pipeline from different Gazprom regional branches were carried out. The first measurement trip was carried out in May, 2003, with the gas transmission company Mostransgaz at the compressor stations and pipelines of the Central Corridor in Davidovskaya and Kursk, south of Moscow. In June, the second trip went to the stations of Uchta and Njukzeniza in Northern Russia operated by Severgazprom. Finally, in October 2003, measurements were conducted at the Kazym station (Tyumentransgaz) in Western Siberia (cf. Fig. 2).

Table 1. Selected stations and surveyed machines and pipeline sections - 2003 measurement campaign

	Shops	Machines	Pipeline		
Stations	**measured**	**No. / power**	**comissioned**		**km (nodes)**
Davidovskaja	1 (electr.)	7x12.5 MW	1985	83-88	300 km (1)
Kursk	1 (gas)	3x22.2MW	1985	83-88	300 km (4)
Uchta	1 (gas)	6x10.0 MW 2x16.0 MW	1982 2001	69-77	1200 km (6)
Njukzeniza	3 (gas)	5x6.0 MW 13x10.0 MW 2x16.0 MW	1986 77-88 2001	69-81	580 km (8)
Kazym	2 (gas)	6x6 MW 6x10.0 MW	1972 1977	71-77	– (6)
5 Stations	8	50 Machines (534 MW)			2380 km (25)

Source: Lechtenböhmer and Dienst et al. (2005)

The scope of the extensive campaign is shown in Table 1. In all, 50 compressors of different types and ages as well as 25 pipeline intersections (nodes) were investigated. Approximately 2,380 km of pipeline was surveyed from the air by helicopter fly-overs. Examples of the screening and measurements at the compressor stations are shown in Figures 3 and 4.

Figure 2: Measurement campaigns on the Russian natural gas export pipelines

Source: Wuppertal Institute 2004

Fig 3: Vent screening; Davidovskaja, May 2003

Fig. 4: Measurements by means of thermo-anemometer

The Gazprom operational data contained detailed information for every machine-hall of the compressor stations and pipeline sections of both corridors, e.g. on machines, running hours, fuel gas usage, maintenance, and breakdowns given for 2003. A significant share of the data could be verified with information collected at the sites during each measurement campaign. Table 2 shows the calculated emission factor for operation-related discharges.

Table 2: Typical emission factors for operations-related discharges from compressor stations and long distance pipelines and for breakdown-related gas losses

Source	Unit per year	Mean value[1)]
Compressor stations		
Start-up/shutdown emiss.	m^3 methane/compressor	15,400[2)]
Shop venting	m^3 methane/shop	105,000
Filter cleaning	m^3 methane/shop	44,359
Long distance pipelines		
Maintenance and repairs	m^3 methane/km	3,750
Breakdowns	m^3 methane/km	284[3)]

1) Specific emission factors based on this with ranges were used for the calculation.
2) Detailed data was used for each machine type for all shops in the northern and central corridors; the emissions range from approx. 200 to 3,900 m^3 per start-up/shutdown cycle depending on type.
3) only methane not ignited

Source: Lechtenböhmer et al., 2005, based on VNIIGAZ/Gazprom, 2004. Zittel 1997; Kaesler et al., 1997. Ramm, 1997. E.ON Ruhrgas, 1998. surveys by WI in 2003

4. Results of Measurement Campaign

The results of the measurements, in combination with a comprehensive set of internal operational data for both export corridors prepared by Gazprom and VNIIGAZ (2004), served as basis for an extrapolation of the results. In Table 3 the results from the methane leak measurements are shown, and in Table 2 the calculations for operation related discharges of methane to the atmosphere are to be found (cf. Lechtenböhmer and Dienst et al., 2005; Lelieveld et al., 2005).

Table 3: Measured methane leaks extrapolated to m^3 per year by component

Component	Unit		Mean value*) of Methane	95% Confidence interval from	to
Compressor stations					
Gas coolers and filters					
Vents	Shop	800	7.468	5.894	9.820
Fittings, valves flanges	Shop	800	860	633	1.146
Combustion, start-up and pulse gas treatment	Gas-powered shops	700	145.270	51.324	420.413
Machinery					
Vents (excl. central vents)	Compressor	4047	437.150	142.963	1.499.602
Fittings, valves, flanges	Compressor	4047	2.434	2.059	2.952
Central vents (during operation)	Compressor	4047	6.302	2.552	16.134
Central vents (outside operation)	Compressor	4047	9.396	8.323	10.491
Seal oil system (degassing tank)	Compressor	4047	27.693	13.101	68.885
Pipelines (valve nodes)					
Vents	Valve node	8145	43.310	27.074	77.829
Fittings, valves flanges	Valve node	8145	3.535	2.455	5.711
*) Arithmetic mean of 10,000 Monte-Carlo simulations; because the probability distributions are not symmetrical, the arithmetic mean is not the mean value of the lower and upper limits of the confidence intervals.					

Source: Lelieveld et al. 2005, supplementary information and measurement campaign 2003, own calculations, Wuppertal Institute 2004

Finally Table 4 summarizes the calculated methane emissions as extrapolated to the Russian long distance transport pipelines. Two thirds of methane emitted came from leaks on fittings of the machines, compressor stations, and valve nodes on the pipelines. Another significant portion is due to the venting of shops and pipelines for maintenance and repair purposes. Taking the worst-case assumptions, venting accounts for almost 22% of methane emissions. Other operations-related emissions are mainly due to gas-regulated fittings and compressor seal oil systems (emissions from degassing tanks). Methane emissions can also be caused by breakdowns (if the gas is not ignited, which is the case in about 40% of all breakdowns) and – indirectly – by the power supply for electric motors.

Table 4: Methane emissions from Russian long distance gas transport system (2003)

Methane emissions by plant section/mode	$10^6 m^3$	Share
Leaks from fittings and vents	2 249	66.5%
Leaks from compressors	1 861	55.0%
Other leaks from compressor stations	7	0.2%
Leaks from pipelines	381	11.3%
Operational (measured) including:	214	6.3%
Fuel gas. start-up gas and pulse gas supply	102	3.0%
Seal oil systems (shaft seals)	112	3.3%
Operational (calculated)	779	23.0%
Compressor start-up/shutdown	42	1.2%
Methane in turbine waste gas	11	0.3%
Maintenance/repairs to stations	152	4.5%
Maintenance/repairs to pipelines	574	17.0%
Breakdowns	44	1.3%
power supply	96	2.8%
Total	3 382	100.0%

Source: own calculations, Lechtenböhmer et al., 2005

Compared to the emission characteristics of the main export corridors as given in Lechtenböhmer and Dienst et al. (2005) the specific emissions of methane are somewhat higher due to a lower load factor of the whole grid compared to the export corridors.

In total the results indicate an overall emission of methane during transport from compressor stations and pipelines within Russia of about 3.4×10^9 m^3 per year. This is equivalent to 0.6% (including underground storage the value is about 0.7%, cp. Lelieveld et al., 2005; Lechtenböhmer et al., 2005). By using the Monte Carlo method to determine the confidence interval for the methane emission value, it found that emissions fall within the range from 0.5 to 1.5 % of the exported gas with 95 % certainty. This is about 7% of the amount of fuel gas used by Gazprom for compression and other purposes.

5. Results of survey of mitigation options

In spite of improvements made by Gazprom in the past decade, the measurement campaign findings shown in Tables 3 to 4 indicate that there are still significant volumes of methane being lost to the atmosphere which can be recovered. At the same time recovery projects could increase profitability and efficiency as has been shown by Robinson et al. (2003) using a marginal abatement cost analysis of Russia's gas transmission infrastructure. They estimate that more than 30% of methane emissions could be mitigated at project investment costs below US$ 10 per ton of CO_2 equivalent.

To identify suitable technical options to exploit this huge potential, this paper presents an analysis of methane recovery projects conducted by US gas transportation companies under the framework of the Natural Gas STAR International partnership with US EPA. The analysis focuses on two technology replacements and three operating practice enhancements that are both valid mitigation options and potentially profitable investment opportunities.

The most promising replacement options are the replacement of centrifugal compressor seal oil systems and the installation of low bleed pneumatic devices. Leaks from compressors and seal oil system losses account for $1973x10^6$ m^3 per year or 58.3% of methane losses from Russia's gas transmission system, as shown in Table 4. The currently used "wet" seal assemblies incur high emissions and a number of additional costs, including energy and maintenance for the seal oil pump skid, make-up seal oil, power loss to overcome drag from seal oil accumulated in the pipeline, and pipeline maintenance for seal oil contamination (Uptigrove, 1987). As wet seals wear out, many pipeline operators in the US, as well as Gazprom at some sites, have replaced them with dry seals, which are mechanically simpler and lower emitting. Although dry seal capital costs are up to 100% higher, this investment is recovered by up to 90% lower operating costs. The typical payback period on the dry seal investment is about 54 months; and is reduced to only 14 months when assigning a conservative value of US$ 7 per tonne of CO_2 equivalent to the avoided emissions. Dry seals have the potential to reduce about 90% of the current losses from vents (excl. central vents) in Table 3 and would eliminate the current losses from the Seal Oil System category in Table 3.

Pneumatic control devices are responsible for a significant share of the fuel and impulse gas preparation units, which are shown to emit about $102x10^6$ m^3 per year in Russia (see Table 4). Older pneumatic devices require larger gas bleed rates for process control, while devices introduced in the 90s achieve the same result without the high bleed rates and generally at the same capital and operating costs. Other options are devices using instrument air, mechanical, or electric devices. Thus low bleed pneumatic devices are appropriate measures to reduce methane emissions from Russia's gas transmission system. Due to the rising value of gas as a sales commodity and as a carbon credit, retrofit or early replacement programs are attractive.

Additional to the replacement options are operational practises that can reduce facility methane emissions while improving efficiency. Three practises shown to be successful by the Natural Gas STAR International program are optimizing compressor shutdown practices, minimizing venting before pipeline maintenance and periodic cost-effective leak inspections.

As compressors are cycled out of service or taken offline for maintenance, it is common operating practice to vent the high-pressure gas in the compressor to the atmosphere through the compressor's central vent. This is a large component of the 42×10^6 m^3 per year of start-up/shutdown emissions (see Table 4). These emissions could be mitigated by either keeping compressors pressurized or by routing the central vent to fuel gas, which only requires minimal facility modification by adding valves and piping. Robinson et al. (2003) estimate the fuel gas retrofit investment cost to be US$ 0.5 per tonne of CO_2 equivalent.

With approximate emissions of 574×10^6 m^3 per year for pipeline-sections and 152×10^6 per year for compressor shops, venting before maintenance is another opportunity to recover methane. Current pipeline venting can be reduced 50% by decreasing the line pressure beforehand e.g. by shutting the valve upstream of the pipeline segment and continuing to operate the downstream compressor. A line segment can be further depressured before it is vented by using portable pull-down compressors. This practice has achieved a 90% reduction in line venting at estimated investment cost of US$ 38.2 per tonne of CO_2 equivalent (Robinson et al., 2003).

Unintentional leaks from the natural gas infrastructure account for $2{,}249 \times 10^6$ m^3 or 66.5% of methane losses from Russia's gas transmission (including compressor seal emissions addressed above, as shown in table 4). The majority of the methane is lost by a small number of components. For example, leak survey results from 13 compressor stations found that 0.5% of the components caused more than 90% of the emissions. Leak inspections can take advantage of this finding. Periodic inspections can be directed only at problem areas specific to a facility where significant leaks can be found that are cost-effective to repair. This mitigation option requires an investment for inspection and for repair of any discovered leaks. Both are largely labor costs and usually provide very quick paybacks on the investment (less than 12 months) if the volume of gas saved is quantified and a value assigned to it. The Rusagas Carbon Offset Project between TransCanada and Gazprom performed directed inspection and maintenance at two Russian compressor stations, where they achieved emission reductions of about 50% as a test for possible Joint Implementation-projects (Venugopal, 2003). In addition, Cherkasytransgas of Ukraine achieved reductions of almost two third at two compressor stations (Mandra and Novakivska, 2003). Robinson et al. (2003) give a 13% reduction, based on Natural Gas STAR International company experience, and they estimate the costs for the Russian situation at only 0.2 US$ per tonne of CO_2 equivalent reduced. The total potential for Russia estimated by Venugopal (2003) is more than $400x10^6$ m^3 gas per year. Regarding the approximately $249x10^6$ m^3 gas per year emitted from leakages at compressors and intersections at pipelines (see also table 4) the total potential might be even bigger.

6. Discussion on emission results and GHG mitigation policy

Having a look at the results for the emissions of the Russian gas export network compared to older studies, it can be stated that the emissions per kilometer of pipeline length were approximately one fifth lower than in the earlier survey by

Gazprom and Ruhrgas in 1996/97 (Table 5). In particular, a significantly reduced number of leaks were found at the individual valve nodes. This is a fact probably due to increased efforts that have been taken since 1997 to reduce emissions such as improved checks and inspections as well as improved sealing of fittings, etc.

Table 5: Comparison of the results of the 1996/97 and 2003 measurement campaigns

	WI 2004	Dedikov 1999	Unit
Pipelines			
Leaks	2,425	2,700	m^3/km*a
Breakdowns	284	700	m^3/km*a
Maintenance & repairs	3,749	4,800	m^3/km*a
Total	**6,458**	**8,200**	**m^3/km*a**
Compressor stations			
Leaks	44,191		m^3/MW *a
Operations-related emissions	5,227		m^3/MW *a
Total	**49,418**	**75,000**	**m^3/MW *a**
*) The difference between Dedikov and WI is due to a more conservative estimate of the operation hours of the central flare.			

Source: Lechtenböhmer et al., 2005, based on: Dedikov et al., 1999 (1996/97 measurements) and Wuppertal Institute, 2003, 2004

Canadian measurements on the Central Corridor (Venugopal, 2003) came up with a significantly lower emission value of approx. 12,000 m^3 per MegaWatt (MW) per year for the leaks from the machines (compared to 44,000 m^3 MW per year from our measurements). However, this difference is completely due to the extremely high emissions from the old 6 MW compressors measured at one shop in Kazym (this shop was also measured in 1996), which are currently being replaced. If these machines, which are not installed at the central corridor, are removed form our data set, the emission factors are well comparable.

An IEA Study (IEA 2006) on the actual and future developments on the Russian natural gas market stressed that the gas transmission sector provides the largest opportunity for GHG reductions. Around 60% of the GHG emissions can be reduced on the pipeline networks, especially at the compressor stations, which confirms the results of our study.

Still, the results of the measurement campaign only reflect the current situation of the emissions that derive from the Russian gas export transport system to Western Europe. Future changes relating to indirect emissions depend on future trends in the origin of the natural gas used in Europe and Russia, on the improvements in technology and infrastructure, as well as overall developments in the international gas supply structure.

Measures based on the extensive experience of the Natural Gas STAR International program, illustrate significant opportunities for technical optimization. These projects have proven to be profitable for operators, where investment costs are paid back by gas sales value, lower operating costs, and/or carbon credits.

In particular, the possibility of selling emissions reductions in carbon markets can provide another revenue stream to move otherwise marginal projects past the required economic threshold. Carbon markets also have great potential to bring investment capital in exchange for rights to the methane emissions removed from the atmosphere.

Based on the experience gained from transmission system projects implemented in various countries, including Russia, the US, and Ukraine, Russia's gas transmission system is in a position to benefit from new sources of revenue provided by carbon markets. As an Annex I signatory, Russia can in principle attract investment from other Kyoto countries by using Kyoto's project-based Joint Implementation (JI) Mechanism to accelerate methane emissions reduction in its gas transmission system. Under JI, project participants from an Annex 1 country may implement an emissions reduction project in the territory of another Annex 1 country, and count the resulting emission reduction units towards meeting its Kyoto target

First experiences with the use of the project-based mechanisms to reduce methane emissions in the Russian oil and gas industry occurred under the UNFCCC program of activities implemented jointly (AIJ). Under AIJ, parties could implement projects on a voluntary basis to reduce GHG emissions; however, no credits could be accrued. Two projects were initially identified, but only one completed: Modeling and Optimization of Grid Operation of the Gas Transportation System "Ushgorod Corridor" of Wolgotransgas (RAO Gazprom and Ruhrgas AG).

Recently, however, project-based activity in the oil and gas sector has increased significantly. Under the Clean Development Mechanism (CDM) there are four approved methodologies (), focusing on "leak reduction at natural gas compressor and distribution stations" (Approved Methodology (AM) 0023), "flare reduction and gas utilization at oil wells and gas processing plants" (AM009 and AM0037), and "gas distribution pipeline replacement" (AM0043). Although no projects have been implemented as yet, there are several in the pipeline. On the JI front, the project implementation picture is much brighter. In Russia alone, there are at least 13 oil and gas-based projects at implementation or in development. 11 are focused on the gas distribution sector, with 7 projects already approved by the Joint Implementation Supervisory Committee (JISC). These projects aim to identify and repair leaking components at natural gas distribution stations. The total potential emission reductions from these 11 projects over a five year crediting period (2008-2012) are 50.4 million metric tons of CO_2 equivalent. Additionally, two projects are focused on reducing flaring and optimizing the utilization of associated gas from oil production fields. The emission reduction potential of these “flaring projects” over the 2008-2012 crediting period (i.e., first commitment period of the Kyoto Protocol) is 1.2 million metric tons of CO_2 equivalent.

These project-based activities illustrate the momentum that is building in the Russian oil and gas sector, as more investors are recognizing opportunities to invest in developing infrastructure to reduce methane emissions.

7. Conclusions

Overall, the new measurements and calculations confirmed that the methane emissions from the Russian natural gas export network are at approx. 0.6 % of the natural gas delivered (0.7 % including underground storage; cp. Lelieveld et al., 2005). By using the Monte Carlo method to determine the confidence interval for the methane emission value, it found that emissions fall within the range from 0.5 to 1.5 % of the exported gas with 95 % certainty. This is about 7% of the amount of fuel gas used by Gazprom for compression and other purposes.

Emissions happening during gas transport are somewhat below the level found by previous measurements. Due to numerous technical and organisational measures taken by Gazprom since the mid 90s, some emission sources have clearly decreased. The decrease is probably a result of technical and organizational measures to better control methane emissions from components, such as regular controls and maintenance, better equipment with leak detection devices, and the development of re-sealing techniques for valves. In other areas there is still a potential to further reduce emissions. The main sources of emissions are primarily leaks or discharges from machines and valves at compressor stations and – to a lesser extent – due to leaks from pipeline valves.

IEA (2006) estimates that the largest share of emission reduction options in the Russian natural gas sector lies in the transmission network. Taken the estimate from Robinson et al. (2003) of a reduction potential of a third of all methane emissions for the Russian natural gas transmission, a first estimate based on our survey of emissions, arrives at about 1×10^9 m^3 of methane that could be captured and exported annually. This is equivalent to 15×10^6 tons of CO_2 equivalent GHG emissions that can be mitigated at costs below US$ 10 per ton, most of it at even lower prices. Gazprom itself estimates the methane mitigation potential to be as high as 1.7×10^9 m^3 and another 0.9×10^9 m^3 by the implementation of low compressor ratio gas transportation regime (IEA 2006, 102). Cost-effective reduction of methane emissions in gas transmission systems is a topic examined extensively and demonstrated successfully by many other long distance gas transmission companies. Drive energy reduction and the huge distribution system offer further large mitigation potentials in Russia.

These facts and the long-term necessity of Gazprom to secure funds for maintenance and re-investment of its huge operating system are important reasons why Gazprom has been among the early supporters of the ratification of the Kyoto Protocol (Grubb and Safonov 2003). Kyoto's flexibility mechanisms allow Annex I signatory countries to help meet their reduction targets by financing projects in other countries. The favorable methane emission mitigation potential of the Russian gas transmission system has established it as an attractive opportunity for investment through JI or other means.

8. Definitions

As not all expressions are self-explanatory, we include some definitions of often used terms.

- valve knots: valves installed every ten to twenty kilometers for stopping gas in an emergency or for maintenance and/or to bypass the gas from one pipeline to another
- valve node vents: used for depressing pipelines to conduct maintenance and for emissions of damages and leakages
- central vents: vents on the rooftop of buildings/machine-halls
- shop venting: venting of the complete machine hall that contains turbines and compressors; all emissions from leakages, wet seals, valves, flanges, armatures etc. are included; emissions are measured at the central vents
- maintenance and repair: depressuring and venting of pipeline segment to conduct maintenance and repair the pipeline
- breakdowns: pipeline damage
- Shop: Typically one compressor station is a combination of several shops (with typically different construction dates and equivalent or differing machine types), each connected to one of the (3 to 10) parallel pipelines forming the corridor (see fig. 1: Typical plan of a plant complex ('Shop') at a compressor station

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